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Head Cabbage Yield and Leaf Calcium as Influenced by Liming a Latosolic Reddish Prairie Soil

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INTRODUCTION

Cabbage production in Hawaii is limited principally to the Kula area of the island of Maui and the Kamuela area of the island of Hawaii. The ash-derived soils in the Kula and Kamuela areas are very similar, having developed under a cool, relatively dry climate.[2] These soils are among the best agricultural soils in Hawaii, having a high cation exchange capacity, high base saturation and near neutral pH, as well as excellent physical properties.

The present study arose when a few cabbage growers in the Kula area reported apparent increases in cabbage yield in response to applications of only 200 to 400 pounds of hydrated lime per acre. Such low rates of lime could not change the soil pH appreciably, thus any yield response, if actually occurring, probably resulted from the added calcium. However, a response to calcium did not seem likely on soils which were known to be well supplied with exchangeable calcium. A field liming experiment was established in an area with a history of more than 10 years of cabbage production to determine the effects of applied lime on cabbage yield.

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[2] In a recent (1962) tentative revision of the classification of Maui soils, the Reddish Prairie soils in the Kula area are designated Kula loam rather than the earlier designation, Waimea loam. The latter name still identifies the Reddish Prairie soils in the Kamuela area.

PROCEDURES

The experimental area was located on a commercial farm[3] adjacent to the Kula Experimental Farm, Hawaii Agricultural Experiment Station, Maui. Two successive cabbage crops were grown to measure the effect of both lime and phosphorus applications. The lime treatments (no lime, 400 pounds hydrated lime per acre, and 15,000 pounds "reject" lime per acre[4]) were established prior to planting the first crop. The low rate of hydrated lime was chosen to approximate farmer practice and test the response of cabbage to added calcium. The high rate of reject lime was to increase the pH from 5.8 to about 6.5 and thus test the combined effect of an increase in both pH and calcium supply. Two phosphorus rates, 0 and 175 pounds P (850 pounds treble-superphosphate) per acre, were included to test the interaction of lime and phosphorus applications. Phosphorus was applied prior to planting each crop. A split-plot design was used, with phosphorus rates as whole plots and lime treatments as sub-plots. Two of the four replicates were placed on an area where the top soil was deep and the other two replicates on an adjacent eroded area. The two soil locations represent near extremes in top soil depth for soils in the Kula series which are used for vegetable production.

In addition to the lime and phosphorus treatments, nitrogen, phosphorus, and potash were applied to the entire area at rates normally used by the grower. For the first crop, about 1500 pounds per acre of 8-20-5 mixed fertilizer were broadcast in the planting furrow, giving the following rates of nutrient elements on an acre basis: 120 pounds N, 130 pounds P, 62 pounds K. The second crop received about 1300 pounds per acre of the mixed fertilizer. The field had received such rates 2 to 3 times every year for several years. No lime had been added previous to the present experiment.

The lime and first application of phosphorus were broadcast and disced into the soil on July 6, 1963. The soil was irrigated and disced again prior to the transplanting of cabbage seedlings July 12 and 13.

The crop was harvested in 2 pickings, September 22 to 25, 1963. The second crop was planted November 15, 1963, and harvested in 5 pickings, January 28 to February 25, 1964. The harvest of the first crop was delayed by rain so that many heads were overripe, causing considerable spoilage.

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[3]The author wishes to express appreciation for the cooperation of the owner and operator, Mr. Robert Umeno.

[4]The hydrated lime was a finely divided commercial grade used in the sugar industry; "reject" lime consists of the large-particle screenings removed in the manufacture of commercial hydrated lime.

The yield area was 120 square feet, i.e., 4 rows spaced 18 inches apart and 20 feet long. In the first crop the average number of heads harvested per plot was 58 (marketable plus unmarketable) with a range of 49 to 69. The wide range in the number of harvested heads was due to both the lack of control in the grower's planting method and a range of 0 to 8 poorly developed plants per plot. Greater uniformity in planting density was achieved in the second crop by marking the field in 2 dimensions and planting on the intersection of lines spaced 18 inches apart. The average number of heads cut in the second crop was 64 with a range of 61 to 66.

Leaf samples for calcium analysis were taken from replicates I and IV of the first crop and from all replicates of the second crop. The first loose leaf next to the head was removed from 10 plants in every plot just prior to harvest. Oven-dried, ground leaf samples weighing 0.5 gram were dry-ashed and analyzed for calcium by the EDTA method described by Barrows and Simpson (*1*). Exchangeable soil calcium was extracted with 1 *N* ammonium acetate and measured by the EDTA method. Leaf potassium was determined by flame photometry.

Soil samples (0- to 8-inch depth) were taken on all plots prior to the application of treatments and on the no-lime, no-P, and high-lime, no-P plots periodically during the year following lime application to determine the change in pH with time on limed plots. Soil reaction was measured with a Photovolt pH meter on a 1:1 soil:water mixture soon after field soil sampling.

RESULTS AND DISCUSSION

Cabbage Yields

The total weight of all heads cut (both marketable and unmarketable) from the first crop is shown for each treatment in table 1. Statistical analysis of these data indicated a significant increase in cabbage yield due to phosphorus but no difference in yield due to lime. The lime-phosphorus interaction was not statistically significant. However, yield data in table 1 show that the largest P effect was in the high-lime plots, where the yield was increased about 11,000 pounds per acre by the application of phosphorus. Plots receiving the high rate of lime but no phosphorus gave the poorest average yield in the experiment, suggesting the possibility of a lime-induced P deficiency.

TABLE 1. Cabbage head yield of first crop as influenced by lime and phosphorus treatments (pounds of green matter per acre)*

Phosphorus treatments	Lime treatments		
	No lime	Hydrated lime (400 lb /acre)	Reject lime (15,000 lb /acre
P pounds/acre	pounds/acre	pounds/acre	pounds/acre
0	67160	65980	64890
175	67790	69150	76050

*P effect significant at 1% level, no lime effect, no interaction.

Since the wide range in number of plants per plot in the first crop could have introduced an error in the analysis of total yield data, a covariance analysis was performed to correct for the effect of plant population on yield. It was observed in the field (especially on the replicates on deep soil) that head weight varied inversely with plant population density, a relationship which would tend to cancel out any influence of differences in plant numbers on total yield. For this reason average head weight was used for covariance calculations rather than the total harvested weight per plot. The covariance analysis showed a significant (5 percent level) average effect of P on head weight and no effect of lime. The average head weight for plots receiving phosphorus was 3.36 pounds and for plots receiving no supplemental phosphorus, 3.18 pounds. Thus the covariance analysis using average head weight gave the same information as total cabbage yield.

Cabbage yield on the second crop was not influenced by either lime or supplemental phosphorus applications. The average yield of 52,660 pounds per acre was comprised of approximately 95 percent marketable heads. The average head weight was 2.27 pounds. Thus, there was no cabbage yield response to the lime treatments on either of the two crops. Cabbage yields were increased by the supplemental 175 pounds P per acre on the first crop but not on the second.

TABLE 2. Calcium content of cabbage leaves* as influenced by lime and supplemental phosphorus applications

Phosphorus treatments	Lime treatments		
	No lime	400 lb. hydrated lime	15,000 lb. reject lime
P, pounds/acre	% Ca	% Ca	% Ca
	1st Crop (2 replicates)		
0	1.44	1.56	1.60
175	1.61	1.76	1.79
	2nd Crop (4 replicates)		
0	2.06	1.82	2.05
175	1.77	2.28	2.04

*The first loose leaf near the head was selected for analysis. Contents are expressed as a percentage of the oven-dried leaf.

Calcium Content of Cabbage Leaves

Leaf calcium contents for both crops are shown in table 2. Data for the first crop show a trend of increased leaf calcium with both lime and phosphorus applications. However, even though the results were relatively consistent on both replicates, the differences were not statistically significant at the 5 percent level, due in part to the small number of experimental units in the analysis. For the second crop all replicates were sampled for leaf analysis, but there was no measured effect of treatment on leaf calcium.

The relationships between cabbage yield and calcium content of leaves for both crops are shown in figure 1. Data from all plots in replicates I and IV of the first crop are presented in graph A of figure 1. Graph B shows data points for all replicates of the second crop. Separate cor-

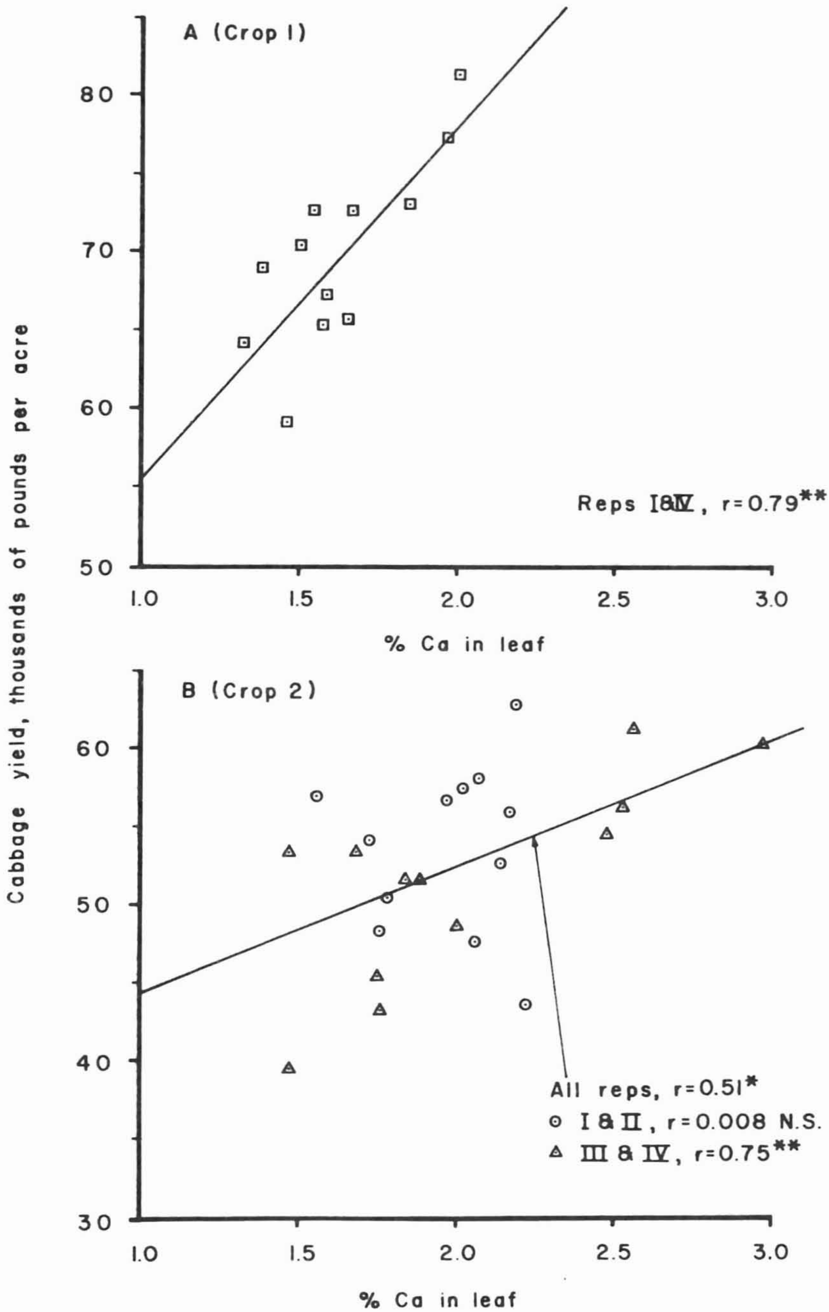

FIGURE 1. Relationships between yield of fresh head cabbage and calcium content of leaves on two successive crops grown on Kula loam.

relation analyses with data from the deep and eroded soil locations for the second crop revealed a higher correlation coefficient for data from the shallow soil (replicates III and IV, $r = 0.75$) than for the combined data of all replicates ($r = 0.51$). There was no linear relationship between leaf calcium and yield for the deep soil (replicates I and II), second crop. The lower average calcium content of leaves and higher average yield in the first crop than in the second are probably related to plant maturity, the first crop having been harvested at a later stage of maturity than the second. The linear relationships shown in figure 1 might be construed to indicate that cabbage yield was somewhat dependent on calcium supply, which in turn would imply a deficiency of calcium where low yields are related to low leaf calcium levels. However, the calcium content of the particular leaf sampled (first loose leaf next to the cabbage head) may not be a good indicator of total calcium uptake since the calcium content of leaves may vary considerably, depending on leaf location and physiological maturity. A deficiency of calcium was apparently not real since cabbage yields were not affected by lime applications for either crop. In addition, even the lowest calcium contents shown in figure 1 do not appear to be at limiting levels. Jackson (*3*) gives a range of 0.4 to 1.8 percent calcium for cabbage tissue, and the lowest value of figure 1 is 1.3 percent.

A comparison of leaf calcium (second crop) and pre-treatment exchangeable soil calcium on selected plots having a wide range of leaf-calcium contents revealed no consistent relationship between soil calcium and leaf calcium. The exchangeable calcium levels in the soil were quite high (23 to 34 milliequivalents Ca per 100 grams) representing calcium saturations of 37 to 53 percent of the total exchange capacity. Calcium deficiency, where noted in the literature (*2*, *5*), occurred only at very low exchangeable calcium levels, e.g., less than 2 milliequivalents per 100 grams soil, or when the exchangeable calcium level was low relative to the level of other cations. In the present case both leaf calcium contents and soil exchangeable calcium levels, as well as the lack of yield response to applied calcium, indicate no deficiency of calcium on the experimental area.

Leaf calcium values for the second crop were also compared with the potassium contents of leaves to explore the possibility that an excess of potassium in the soil may have reduced both calcium uptake and yield, giving a positive correlation between yield and leaf calcium. However, no calcium-potassium relationship was found. Thus, there is no explanation at hand for the positive correlation between cabbage yields and calcium content of leaves.

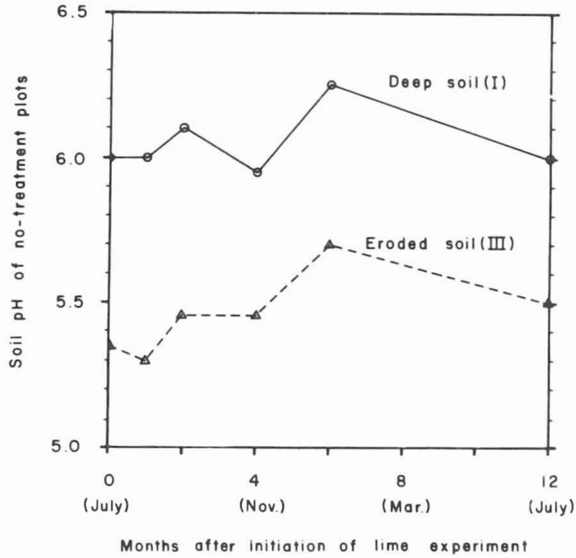

FIGURE 2. Soil pH of no-treatment plots in two replicates during year of lime-phosphorus experiment on cabbage. Kula loam, Maui, 1963–64.

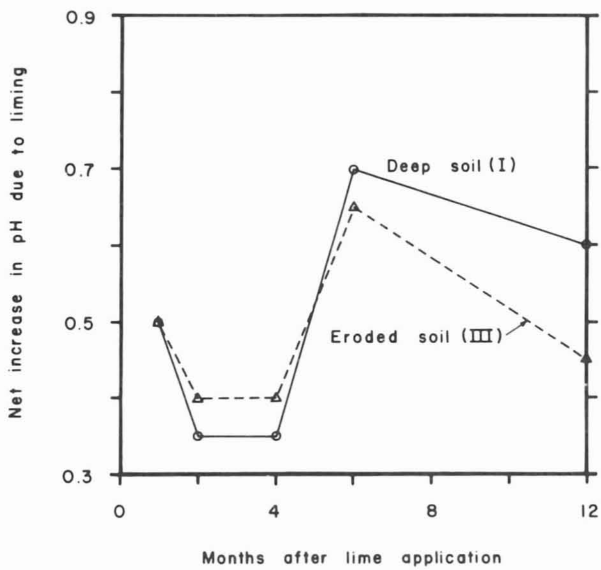

FIGURE 3. Net increase in soil pH after application of reject lime (15,000 pounds per acre) to Kula loam. ("Net increase in pH" is the difference in pH between the limed and unlimed plots, corrected for the pH difference of the plots before treatment).

Soil pH

The pH of unlimed soil was found to vary by as much as 0.4 pH units during a 6-month period (figure 2). Increases in soil acidity concomitant with decreases in soil moisture have been measured in many Hawaiian soils (*4*). Such seasonal variations in pH are probably accompanied by numerous chemical and biochemical changes which could alter the availability of nutrients. The solubilities of phosphorus compounds in the soil are especially sensitive to changes in pH. Thus, in the present study the difference in yield response of the first and second cabbage crops to applied phosphorus might have been related to the seasonal variation in pH. Seasonal variation in soil temperature might also have been responsible for the variable P response, as demonstrated by Power et al. in a study with barley (*6*).

Data in figure 3 show that the maximum pH increase, resulting from application of 15,000 pounds of reject lime, occurred 6 months after lime incorporation. The rapid pH increase between 4 and 6 months was probably the result of further mixing of lime and soil with cultivation prior to the second planting of cabbage the fourth month (November). Although the actual pH of deep and eroded soil differed considerably (figure 2), the net change in pH due to liming was nearly the same at both locations (figure 3). Analysis for residual carbonates revealed that the percentage of applied lime remaining in the soil as calcium carbonate 12 months after application was 12 and 14 percent on the deep and eroded soil, respectively.

SUMMARY AND CONCLUSIONS

A field experiment was conducted with head cabbage on the Kula loam soil of Maui to determine the effect of lime application on cabbage yield and calcium uptake. Measurements were made on two successive crops on a field that had been cropped to cabbage almost continuously for over 10 years. Lime was applied at 3 rates: none, 400 pounds hydrated lime, and 15,000 pounds reject lime per acre. Supplemental phosphorus was applied prior to planting each crop at 2 rates: none and 175 pounds P per acre. The treatments were applied in addition to the fertilizer normally applied by the grower. Other cultural practices were conducted by the grower in the usual manner.

There was no cabbage yield response to lime applications at either low or high rates with either crop. The supplemental phosphorus application increased yields on the first crop but not on the second. The yield response to phosphorus on the first crop was greatest on the high-lime plots where an increase of about 17 percent or 11,000 pounds of fresh cabbage per acre, was obtained.

Cabbage leaf samples were taken just prior to harvest. There was a trend of increased calcium in the leaf with both lime and phosphorus applications on the first crop, but no treatment effects were evident on the second crop. Significant positive correlations between leaf calcium contents and cabbage yields were obtained on both crops. There is no apparent reason for such a correlation in view of (1) the lack of yield response to lime additions, (2) the high percentage calcium in leaves, and (3) the high exchangeable calcium level in the soil. An understanding of the yield-leaf calcium relationship shown in figure 1 awaits definitive research on the uptake and distribution of calcium in the cabbage plant at various stages of development.

In conclusion, it is doubtful that lime applications will increase head cabbage yields on the Kula soil under normal cabbage culture. Exchangeable calcium levels are quite high on this soil so that calcium deficiency is unlikely. Since the commonly accepted optimum pH range for cabbage is about 5.8 to 7.2, liming may be beneficial for reasons other than calcium supply at pH values below 5.8. Lime, when applied in large quantities to alter the soil pH, should be incorporated sufficiently in advance of fertilizer application and planting to avoid fixation of applied phosphorus and damage to plant roots.

LITERATURE CITED

1. Barrows, H. L., and E. C. Simpson. 1962. An EDTA method for the direct routine determination of calcium and magnesium in soils and plant tissue. Soil Sci. Soc. Amer. Proc. 26: 443–445.

2. Colwell, W. E., and N. C. Brady. 1945. The effect of calcium on yield and quality of large-seeded type peanuts. Jour. Amer. Soc. Agron. 37: 413–428.

3. Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood, N. J. P. 329.

4. Kanehiro, Y., Y. Matsusaka, and G. D. Sherman. 1951. The seasonal variation in pH of Hawaiian soils. Hawaii Agr. Exp. Sta. Tech. Bull. 14. 19 pp.

5. Melsted, S. W. 1953. Some observed calcium deficiencies in corn under field conditions. Soil Sci. Soc. Amer. Proc. 17: 52–54.

5. Power, J. F., D. L. Grunes, W. O. Willis, and G. A. Reichman. 1963. Soil temperature and phosphorus effects upon barley growth. Agron. Jour. 55: 389–392.

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